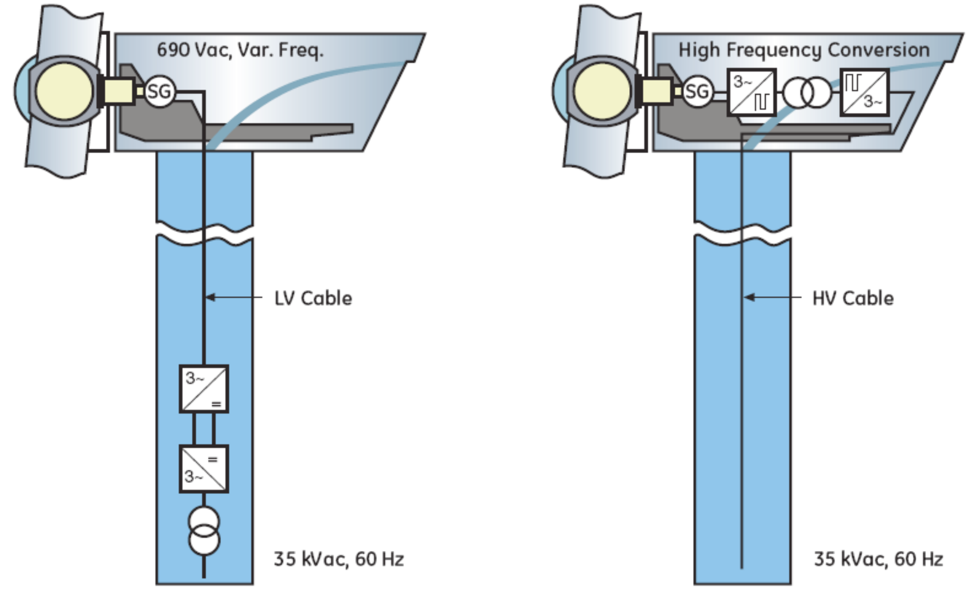
SiC Enabled Medium Voltage Drive for Wind Power Conversion

Advancing state-of-the-art high frequency, medium voltage drives with SiC transistors for efficiency and reliability gains in a smaller footprint



Left: a typical wind turbine contains power conversion elements down the post because of space requirements for the motor and gearing. Right: Innovative use of SiC-based HV power conversion allows all the necessary equipment to be co-located in motor housing saving on overall system costs. *Images courtesy of GE Global Research*

Electric drives are key enabling technologies for many applications including advancing wind power conversion. Typical wind turbine housings contain gearing and a generator to convert wind energy to electricity; however the power must pass through converters to shape the voltage and current to match the grid. These converters take the alternating current from the generator and pass a clean, controllable waveform to the power grid. Such control makes wind power more amenable to grid operators and improves integration of a renewable energy source. Modern, silicon-based power electronics are limited by switching frequency, so additional filtering is necessary to convert power from the generator. The large footprint of converters means they are often placed down the turbine tower.

Advanced silicon carbide (SiC) based drives could provide the quality high-frequency (HF) power conversion needed for reliable, efficient operation, while significantly reducing the overall footprint of the drive. The smaller footprint could allow all components to be housed in the turbine itself. Advances in insulation would further reduce the size. Together, the smaller drive and motor improves the utility of wind power while achieving system-level reductions in size, weight, and cost of ownership. Such improvements potentially open new applications for MV motors, especially where space is at a premium.

Benefits for Our Industry and Our Nation

This project will help drive adoption of MV HF drives in a wide range of applications, especially in the wind and aviation industries. The innovative use of SiC enabled drives will deliver a competitive technical advantage in system-level efficiency and power density with additional benefits in reduced capital and operational expenditures. In particular, the smaller footprint of the drive and the clean output waveform made possible by SiC power electronics alleviates the space limitations in wind turbines. The proposed technology can improve power density for MV HF converters by a factor of two while cutting losses by an equal factor of two, which will improve the efficiency of the inverter section to 99%. Moreover, the insulation system developed under this program will be an important enabler for driving the compact high frequency transformer with advanced SiC drives.

Applications in Our Nation's Industry

This project will develop a megawatt-class ”transformerless” electric drive that can be integrated with a wind turbine generator to meet challenging requirements for performance, efficiency, and footprint. This technology advancement will be especially valuable for doubly fed induction generators (DFIG), which are becoming essential to large wind turbines, but could also apply to aviation applications. Other applications may include improving navy and marine operations as well as in high-speed pump motors for above-ground and down-hole pump operations. Advanced SiC power electronics could also enable inverters for battery energy storage and uninterruptible power supplies as well as transformer-less industrial variable speed drives.

Project Description

The project objective is to develop, test, and optimize two high frequency, medium voltage drives using SiC enabled power electronics. The drives will be demonstrated and integrated with a 60Hz MV generator and a high-speed generator for industrial applications, especially in the wind energy industry. The proposed MV drives will leverage existing SiC transistor technology and a novel modular drive topology to enable low-cost automated manufacturing. To integrate the HF drive with the high-speed generator, a MV insulation system for the drive filter will be developed that can handle the high rates of change in voltage levels associated with the HF drive and reduce losses associated with induced magnetic fields. Finally, advances in the insulation will further support the HF transformer and SiC power block, which will reduce the final footprint and increase the power density of the system.

Barriers

- Achieving the combined high power density through size reduction at the system-level.
- Designing and implementing a MW-scale drive with discrete series devices of lower voltage rating.
- High frequency stress on the filter and stator insulation systems due to high rates of change in voltage.
- High frequency transformer with high insulation level.

Pathways

Partners will divide the project into three main tasks: developing the MV SiC power block; integrating, testing, and validating the drive at a wind conversion test-bed; and creating a technology to market plan. Development of the drive will build off of proven architectures and existing commercial products and techniques. Integration and testing with both a DFIG used in wind turbines and a grid connection setup will proceed at existing test facilities. Finally, the team will develop the market launch plan throughout the course of the project period.

Milestones

This three year project began in 2016.

- Develop HF MV drive with >97% efficiency (2018).
- Design and test new insulation systems for both the filter and the high-frequency transformer (2018).
- Build and test HF, MV SiC enabled drive including the power electronics, phase modules, magnetics, and controls (2018).
- Test and validate system integration of SiC MV drives with permanent magnet motors (2019).

Commercialization

Beyond the technical barriers addressed in this project, two challenges to commercialization of the technology prototype are (1) the challenging operating environment in the wind energy industry, and (2) developing a manufacturing process for a novel SiC converter. A technology transition team will work closely with project investigators to ensure these barriers are addressed and will develop a tech-to-market plan and report that summarizes the commercialization strategy. GE Global Research will work closely with GE Renewable Energy and GE Energy Connections to define and analyze market segments. Additionally, the team will leverage GE's commitment to SiC manufacturing with the New York Power Electronics Manufacturing Consortium. Market opportunities for the high-performance SiC drive developed will also be explored for applications beyond the wind energy sector, including potential aviation and industrial applications.

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DOE/EE-1430 • March 2017